Content Provision under Digital Rights Management

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1 Introduction

Piracy of digital goods has become a large problem on the Internet due to its ability to distribute large quantities of content to large quantities of people at very low cost. As a result, many digital content producers have turned to technology to insure their revenue stream. These technologies, collectively known as *Digital Rights Management (DRM)* technologies, use encryption and other security technologies to artificially restrict the uses of a digital good.

An example of DRM is Apple's iTunes FairPlay technology[1] for its iTunes Music Store. All songs downloaded from the store are encrypted by Apple. Apple's iTunes Music Player, when so authorized by Apple, will decrypt and play these songs. Apple will only authorize computers after users have paid for the music. Apple has a set of policies listing what they permit users to do with songs, including (as of September 6, 2005):

- Authorize up to 5 computers to play the songs
- Transfer any songs to an iPod portable music device
- Burn songs to CD an unlimited number of times
- Burn any single playlist of music to CD up to 7 times
- Re-download the encrypted songs from iTunes Music Store

Note that in this example, Apple does not permit their users to copy the music to friends very easily. Normal music files do not have this restriction, and the only reason this restriction exists is that it was artificially put there by Apple's DRM technology. Also notice that the iTunes Music Player (which runs on the local user's computer) has the decryption keys stored on the hard drive so that it can play the music. A sufficiently sophisticated user can always find these keys, decrypt the music files themselves, and save un-encrypted and therefore unrestricted copies. However, this act of 'circumvention' is costly and time-consuming, and many users either don't have the requisite skills or decide that they would rather just pay for the music and live with Apple's restrictions.

DRM technologies have many effects that must be understood. They reduce the utility to consumers of digital content by restricting its use. By preventing piracy, they can increase the content producer's profit. A side effect of increased profit is an increased incentive for innovation, leading to more digital content being available. (Scotchmer, 2004) DRM technologies also have strategic considerations for pricing (Park and Scotchmer, 2004) and flexibility of use (Bergemann, Eisenbach, Feigenbaum, and Shenker, 2005).

Not all digital piracy is bad for the content producers. Oberholzer and Strumpf (2004) do an empirical study of the music industry and find that despite widespread piracy, the industry is quite healthy. Givon, Mahajan, and Muller (1995) use an information diffusion model to estimate that the UK software industry sees increased sales (on the order of 70%) due to word-of-mouth recommendations of pirated users. And Sundararajan (2004) develops an economic model of piracy that includes these beneficial effects of piracy and attempts to develop strategies for profit maximization that include anti-piracy efforts. This paper, however, does not deal with this aspect of piracy. I assume that there are no positive producer benefits from piracy (obviously the pirate user benefits).

I develop a idea that was first observed by Acquisti (2004). In that paper, Acquisti develops a model of platform adoption in the presence of network effects. The DRM technology makes transferring between two networks (open and DRM networks) possible, but one direction is costless (open $\longrightarrow$ DRM) and the other costly (DRM $\longrightarrow$ open). In addition to other results, Acquisti derives a result that popular content is more

[1] http://www.apple.com/iTunes/

likely than niche content to be transferred to the open platform if it is initially only available on the DRM platform. He therefore concludes that the success of a DRM platform depends on 'user-generated' content (as opposed to 'widely-popular vendor-generated' content.

I use this idea as a basis for studying incentives for innovation in a content industry that uses DRM technologies. I study the situation where there is a negative network effect in the costs of 'breaking' the DRM, or transferring the content from the DRM platform to the open platform. As content becomes more popular, the average cost of breaking decreases since the content will more likely fall into the hands of people capable of breaking it, hackers will be more interested in breaking it because it can be shared farther, or there exist returns to scale to breaking DRM technologies. In this situation, I hypothesize that content producers will prefer high-value 'niche' content over low-value 'mass-market' content when using DRM. Here I study the implications of such a preference.

Our model builds upon the model of DRM technologies initially developed by Park and Scotchmer (2004). I modify this model to include network effects in the cost of breaking the DRM protection. This is a supply-side network effect, which has not been studied much in the literature. In order to study different types of content, I use a model of content originally developed by MacKie-Mason, Shenker, and Varian (1996). I expand on their definitions slightly to allow greater flexibility in decisions of content providers.

2 Model

The DRM industry has three classes of agents: Content Producers, Platform Providers, and Consumers. This is very similar to what economists are currently calling a "two sided market." (Rochet and Tirole, 2003) Content producers want to sell their content to consumers, but have the problem that consumers can then do many things with this content that the producers don't want them to, such as share it on the Internet with the consumer's closest million friends. Platform providers have the technology that enables consumers to use content, but only if producers have placed their content on the platform.

All digital content must exist on some type of platform, or combination of hardware and software that can be used to view/use/access the content. DRM platforms are content platforms that include some technology that attempts to artificially restrict the content's use beyond what would normally be implied by standard technology and legal controls. DRM platform providers then have to convince both the content producers and the consumers simultaneously to use their platform to access content.

I model the decision that faces a content producer. Following Park and Scotchmer (2004), my model of DRM technology has the producer choosing some level of protection, e. This protection has cost $K(e)$, with $K'(e) > 0$ and $K''(e) > 0$. Consumers can purchase this content at price $p(q)$ from the producer, or they can break the DRM at cost $b(e)$, with $b'(e) > 0$. (Note that Park and Scotchmer have $b(e) = e$). Quantity q will be purchased at price $p(q)$. Therefore, the producer's decision problem is

$$\max_{p,e} p(q) \cdot q - K(e)$$

such that

$$p(q) \leq b(e)$$

I now modify this model to include network effects in the cost of breaking. Formally, I redefine the function $b(\cdot)$ to take a second parameter, $\hat{q}$, which is the expected quantity of content that consumers possess. Therefore, the producer maximization problem is that I consider here is:

$$\max_{p,e} p(q) \cdot q - K(e) \tag{1}$$

such that

$$p(q) \leq b(e, \hat{q})$$

Finally, in equilibrium, I set $\hat{q} = q$ to become a fulfilled-expectations equilibrium. (Katz and Shaprio, 1985)

I assume that $\frac{\partial b(e,\hat{q})}{\partial \hat{q}} < 0$, which means that the cost of breaking decreases as the content becomes more popular.

Next I model the possible content types that a producer can choose to produce. For simplicity, I assume that content has a linear demand parameterized by $\bar{p}$ and $\bar{q}$. The demand function is therefore

$$p_{\bar{p},\bar{q}}(q) = \bar{p}\left(1 - \frac{q}{\bar{q}}\right) \tag{2}$$

Following MacKie-Mason et al. (1996), I vary content along two axes: content can either be high-value ($\bar{p} = p^H$) or low-value ($\bar{p} = p^L$), and content can either be mass-market ($\bar{q} = q^M$) or niche ($\bar{q} = q^N$). These four types of content are illustrated in Figure 1.

3 Results

To solve this model, I proceed using a method similar to that which Economides used for network effects. (Economides, 1996) I first solve for the optimal level of protection e in terms of both the actual quantity sold,

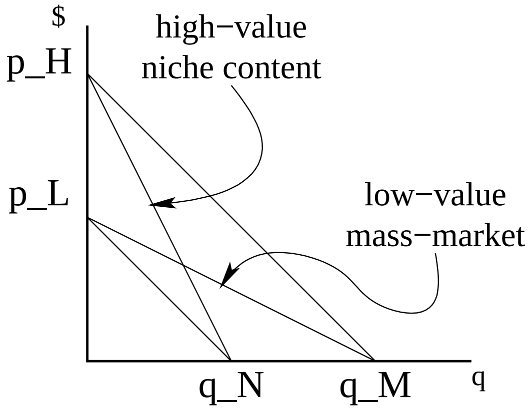

Figure 1: Four types of Content

and the quantity expected to be sold. I then proceed with the maximization of producer utility. Finally, I impose the fulfilled expectations condition.

Now, I define a function $f(q, \hat{q})$:

$$f(q, \hat{q}) = \{e | b(e, \hat{q}) = p(q)\}$$
$$= b^{-1}(p(q), \hat{q})$$

f is a function at gives the level of protection e needed to achieve sales of q items given consumer expectations at level $\hat{q}$.

The producer decision now can be written as

$$\max_q p(q) \cdot q - K(f(q, \hat{q}))$$

After solving this for q, I can impose the fulfilled expectations condition to arrive at the final profit.

For comparison, a pure monopolist's decision (absent illegitimate copying) is

$$\max_q p(q) \cdot q$$

I can now show some interesting comparative statics about my model. But first I will describe a useful theorem from the paper 'Monotone Comparative Statics' by Milgrom and Shannon. A function $f(x, t)$ has *increasing differences* in (x, t) if $\forall x' \geq x'', t' \geq t'' f(x', t') - f(x', t'') \geq f(x'', t') - f(x'', t'')$, or $f(x, t') - f(x, t'')$ is increasing in x. Now the useful theorem:

Theorem 1 *Let $f : \mathbb{R} \times \mathbb{R} \to \mathbb{R}$. If $f(x, t)$ has increasing differences in (x, t), then* $\text{argmax}_x f(x, t)$ *is weakly increasing in t.*

PROOF This theorem is shown in more general form as Theorem 5 in Milgrom and Shannon (1994). ∎

Now I can compare the producer's decisions about quantity and price under monopoly and under DRM:

Lemma 1 *In a world where a producer has to use DRM to prevent copying, he sells more units at a lower price than he would as a monopolist, as long as $\frac{\partial f}{\partial q} + \frac{\partial f}{\partial \hat{q}} < 0$. If this condition is reversed, then he sells fewer goods at a higher price.*

PROOF Define $h(q, t) = p(q) \cdot q - t \cdot K(f(q, \hat{q}))$. Notice here that $t = 0$ corresponds to the monopolist's decision problem, and $t = 1$ corresponds to a DRM producer's decision problem. I want to show that $h(q, t)$ has *increasing differences* in (q, t). If $h(q, t)$ has increasing differences, then by the Theorem 1 above, $\text{argmax}_q\ h(q, t)$ is increasing in t. This would mean that the producer's optimal q is greater in a DRM world than as a monopolist. A direct consequence of this is that the price charged is less (assuming downward-sloping demand curves).

To show increasing differences of $h(q, t)$, I need to show that $h(q, t') - h(q, t'')$ is increasing in q for $t' > t''$:

$$h(q, t') - h(q, t'') = p(q) \cdot q - t' \cdot K(f(q, q)) -$$
$$(p(q) \cdot q - t'' \cdot K(f(q, q)))$$
$$= (t'' - t') \cdot K(f(q, q))$$

Since $t'' - t' < 0$, what remains is to show that $K'(f(q, q)) \cdot f'(q, q) < 0$ Now $K' > 0$ by assumption. Now, I need $f'(q, q) = f_1(q, q) + f_2(q, q) < 0$. Remember that $f(q, \hat{q}) = b^{-1}(p(q), \hat{q})$. Now $b_e > 0$, so $b_p^{-1} > 0$, and $b_q^{-1} = b_p^{-1} \cdot p_q < 0$. Therefore, $f_1 < 0$.

If we define $h(q, t) = p(q) \cdot q + t \cdot K(f(q, \hat{q}))$, then $t = 0$ is still the monopoly situation, and $t = -1$ is the DRM problem. It can be shown that $h(q, t)$ has increasing differences iff $f_1 + f_2 > 0$. By the theorem above, this $h(q, t$ having I.D. means that the producer's chosen q is higher under monopoly than DRM. ∎

This result makes sense. In the DRM world, a content producer has to compete with illegitimate copies of its own content. It can set the price of the illegitimate copies, but only at a cost. (This is similar to the literature on raising rivals costs (Salop and Scheffman, 1983) in antitrust economics.) This competition forces it to lower prices and increase demand. A similar result was in Park and Scotchmer (2004).

The condition also makes sense. It basically says a producer will only lower quantity to fight off piracy when lowering quantity has more benefit in the battle than raising the strength of DRM does.

Now I use a numerical example to prove my main proposition:

Proposition 1 *There exists a situation where a monopoly content provider would be indifferent between niche and mass-market goods, but a content provider using DRM would prefer a niche good to a mass-market good.*

PROOF Assume the following:

$$p(q) = \bar{p}\left(1 - \frac{q}{\bar{q}}\right) \qquad b(q, \hat{q}) = e - \frac{1}{4}\hat{q}$$

$$K(e) = \alpha \cdot e^2 \qquad b^{-1}(p, \hat{q}) = p + \frac{1}{4}\hat{q}$$

$$b^{-1}(q, \hat{q}) = f(q, \hat{q}) = \bar{p}\left(1 - \frac{q}{\bar{q}}\right) + \frac{1}{4}\hat{q}$$

Solving the profit maximization problem, we find that

$$q = \frac{\bar{p} + 2\alpha\frac{\bar{p}}{\bar{q}}\left(\bar{p} + \hat{q}\right)}{2\frac{\bar{p}}{\bar{q}} + 2\alpha\left(\frac{\bar{p}}{\bar{q}}\right)^2}$$

Here we let $\alpha = 1$. Now, we have two goods that were defined above:

$$\text{Niche:} \quad \bar{p} = 2, \bar{q} = 1$$
$$\text{Mass Market:} \quad \bar{p} = 1, \bar{q} = 2$$

With the linear demand curve we use, a monopolist will always set $p^* = \frac{1}{2}\bar{p}$, $q^* = \frac{1}{2}\bar{q}$, and $\pi = \frac{1}{4}\bar{p}\bar{q}$. As such, a monopolist would be indifferent between these two goods.

By plugging in these numbers, it is easy to see that profit for the niche good is greater than the profit for the mass market good under DRM. ∎

4 Various Effects of DRM

In this research, I take a consumer-centric approach, studying the effects of this insight on consumer welfare. Since the use of DRM technology is voluntary on the part of the content producer, it will only undertake this technology if it improves its welfare. I are primarily concerned with public policy questions: Is this change in content provision troubling? What policy levers exist for lawmakers to correct for this content provision?

To understand the effects on consumer welfare, I compare the DRM situation with the no-DRM situation. The no-DRM situation is not straightforward to model either. I begin by looking at two simplified extremes as strawmen: that in which illegal copying doesn't happen (this corresponds to the 'perfect legal enforcement' world of Park and Scotchmer (2004)), and that of fully-rational consumers (who, in the absence of DRM, copy everything and never pay). These are both extremes, and neither of these exist in the real world. However, it is illustrative to study them as the real world is somewhere between them.

I model the no-copying world as a normal monopoly situation. The producer attempts to maximize $p \cdot q$. Since my demands are linear, he would always choose $\frac{1}{2}\bar{p}$ and consequently $\frac{1}{2}\bar{q}$, leaving profits $\frac{1}{4}\bar{p}\bar{q}$. He will choose content in the 'normal' ordering.

In the fully-rational world, consumers will choose to copy content if at all possible. To incorporate this into my model, force $e = 0$. Consumers have the choice of paying price p or copying for $b(0, \hat{q})$. For simplicity, assume that when $b(0, \hat{q}) = b_0$ for all $\hat{q}$. This means that the base cost of copying b_0 is constant and independent of both quantity sold and DRM technology. In this world, a producer will be forced to choose $p = b_0$ if they want any sales at all. Therefore, his surplus will be $b_0 \cdot p^{-1}(b_0) = b_0 \cdot \bar{q}\left(1 - \frac{b_0}{\bar{p}}\right)$. He will choose content ordered primarily by $\bar{q}$, preferring mass-market content over niche content.

I also consider some intermediate world. For example, consider the world where there are α consumers who refuse to copy, and $1 - \alpha$ consumers who are fully rational.

I also consider heterogeneity of consumers breaking cost. Consider a cumulative distribution function $F(b; e, \hat{q})$ where F is the proportion of the population who's breaking cost is less than b. If I assume $F(\cdot; e', \hat{q}) >_{\text{FSD}} F(\cdot; e, \hat{q})$ when $e' > e$, then I have a similar model to that given above. This heterogeneity can be because of different skills, or it can be because of differences in consumers distaste for illegal copying.

I am also concerned with the choice of competing DRM technologies. Consider multiple DRM platform vendors, each of which offer different levels of protection at different costs. Are their strategic considerations that competition in DRM platforms bring about that effect consumer welfare? There are many issues here including adoption decisions including network effects.

Another line of inquiry concerns the concept of a 'class break.' A class break is what happens when a hacker breaks the underlying security technology, thereby also breaking all current and future instances of that technology. (Chen, Kataria, and Krishnan, 2005) A class break would break the encryption protecting the content, leaving all content on the DRM platform available for copying. If the cost or likelihood of a class break depends on the total number of copies of content sold (or on the average quantity per piece of content, or on the quantity of the most popular piece of content), then a DRM platform provider may have an incentive to restrict what content is available on his platform. They may prefer high-value niche content to try to keep the incentives for a class break low. How does this situation compare to an 'aware' network from MacKie-Mason et al. (1996)? Does this lead to a 'natural oligopoly' where there is a diversity of DRM platforms each of which have a moderate amount of content?

This research also raises a question of content provision under different innovation incentive schemes. For example, are there likely to be different types of content created when there is a reward scheme rather than an intellectual property scheme, as in Shavell and van Ypersele (2001)?.

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